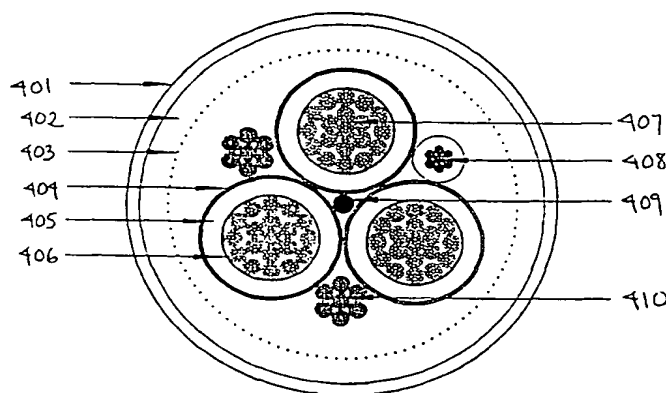


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(54) Title: URETHANE-BASED COATING FOR MINING CABLE



(57) Abstract

A cable (10) adapted for harsh and abrasive environments is provided. The cable (10) has at least one conductor (12, 14, 16) within a jacket (16); and a urethane-based coating over the jacket (16). According to one aspect of the invention, the urethane-based coating is a thermoplastic material. The thermoplastic material preferably has tensile strength which breaks in the range of 20 to 50 MPa; an elongation at break in the range of 150 to 700 percent; a durometer hardness in the range of 60 Shore A to 75 Shore D; and abrasion resistance in the range of 0.01 to 0.05 cm³ volume loss measured using the method outlined in ISO-4649-1985(E). An adhesive is preferably used to bond the thermoplastic material of the coating to the jacket of the cable. According to a more advantageous aspect of the invention, the urethane-based coating is a thermoset material. The thermoset material preferably includes a filler system selected from the group consisting of: carbon black, non-black inorganic filler, and any combination thereof. The thermoset material is preferably co-extruded with the jacket, so no adhesive is needed. The thermoset material preferably has: a tensile strength at break in the range of 14 to 31 MPa; an elongation at break in the range of 150 to 750 percent; a durometer hardness in the range of 40 Shore A to 95 Shore A; and abrasion resistance in the range of 0.050 to 0.10 cm³ volume loss measured using the method outlined in ISO-4649-1985(E). Processes of providing the urethane-based coating over the cable jacket are also provided.

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URETHANE-BASED COATING FOR MINING CABLE

TECHNICAL FIELD

The invention generally relates to a urethane-based coating for improving the damage resistance of cables used in high abrasion service applications, such as mining.

BACKGROUND OF THE INVENTION

A conventional power or telecommunications cable is constructed of one or more insulated conductors with a protective outer jacket. An electrical power cable is typically constructed with conductors formed of copper wire for efficiently conducting electrical power on whatever scale is desired. A telecommunications cable is typically constructed of relatively small wire conductors for conducting electrical signals or, more recently, fiber-optic strands for conducting optical signals.

In applications where multiple conductor paths and/or increased flexibility of the cable is desired, a plurality of conductors are bundled together to form a conductor core. For example in a typical electrical power cable, three or more insulated electrical conductors are separately insulated and intertwined together in a helical arrangement and enclosed in a protective outer jacket. Intertwining the conductors increases the flexibility of the cable but causes the intertwined conductors to have an irregular surface and forms interstices between the individual conductors and between the conductors and an inner surface of the jacket. In a telecommunications cable, a greater number of individual conductors are often intertwined together in more complex helical arrangements, which can include, for example, multiple bundles of helically twisted cables and the bundles are in turn intertwined in a helical arrangement. In the typical electrical or telecommunications cable, the interstices between the conductors are filled to form a generally circular cross-section cable.

Power and telecommunications cables are used in many environments. One of the harshest environments for cables is coal and other mining operations. In particular, the cables used in mining operations tend to be subjected to severe abrasion as the cables are positioned and as equipment, traffic, and mining materials are moved over or along the mining cable. There has

1 been a long-felt need for a improved mining cable that is capable of performing well in this harsh
2 environment.

4 SUMMARY OF THE INVENTION

5 According to the invention, a cable adapted for harsh and abrasive environments is
6 provided. The cable has at least one conductor within a jacket; and a urethane-based coating over
7 the jacket.

8 According to one aspect of the invention, the urethane-based coating is a thermoplastic
9 material. The thermoplastic material preferably has: a tensile strength at break in the range of
10 3,000 to 8,000 psi (20 to 55 mega Pascals (MPa)); an elongation at break in the range of 150 to
11 700 percent; a durometer hardness in the range of 60 Shore A to 75 Shore D; and abrasion
12 resistance in the range of 0.4 to 3.2 mg measured according to the Taber Abrasion method using
13 1,000 g wt and 5,000 revolutions, and more preferably, an abrasion resistance in the range of 0.01
14 - 0.05 cm³ volume loss when tested in accordance with ISO-4649-1985(E), a copy of which is
15 attached hereto as appendix A and incorporated herein by reference. (This standard is
16 substantially similar to DIN standard 53516). An adhesive is preferably used to bond the
17 thermoplastic material of the coating to the jacket of the cable.

18 According to another aspect of the invention, the urethane-based coating is a thermoset
19 material, which is preferred over the thermoplastic material. The thermoset material preferably
20 includes a filler system selected from the group consisting of: carbon black, a non-black inorganic
21 filler (such as kaolin clay or hydrated silica), and any combination thereof. The thermoset material
22 is preferably co-extruded with the jacket, so no adhesive is needed. The thermoset material
23 preferably has: a tensile strength at break in the range of 2,000 to 4,500 psi (14 to 34 MPa); an
24 elongation at break in the range of 150 to 750 percent; a durometer hardness in the range of 40
25 Shore A to 95 Shore A; and abrasion resistance in the range of 1.0 to 1.50 mg measured
26 according to the Taber Abrasion method using 1,000 g wt and 5,000 revolutions, and more
27 preferably, an abrasion resistance in the range of 0.05 to 0.10 cm³ volume loss when tested in
28 accordance with ISO-4649-1985(E). Processes of providing the urethane-based coating over the
29 cable jacket are also provided.

30 These and other aspects and advantages of the invention will become apparent to persons
31 skilled in the art from the following drawings and detailed description of a presently most
32 preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawings are incorporated into and form a part of the specification to provide illustrative examples of the present invention and to explain the principles of the invention. The drawings are only for purposes of illustrating preferred and alternate embodiments of how the invention can be made and used. It is to be understood, of course, that the drawings are not to engineering scale, but are merely intended to represent and illustrate the concepts of the invention. The drawings are not to be construed as limiting the invention to only the illustrated and described examples. Various advantages and features of the present invention will be apparent from a consideration of the accompanying drawings in which:

FIG. 1 is a perspective view with a partially broken away portion of a representative jacketed cable, including optional rip cords, which can be provided a urethane-based coating according to the present invention;

FIG. 2 is a cross-sectional view of the cable in FIG. 1 taken along line 2-2;

FIG. 3 is a cross-sectional view of a second embodiment of cable illustrating an alternative rip cord position;

FIG. 4 is a cross-sectional view of a third embodiment of a representative cable according to a presently most-preferred embodiment of the invention, without rip cords, wherein the cable has a circular cross section; and

FIG. 5 is a cross-sectional view of a fourth embodiment of a cable according to another presently most-preferred embodiment of the invention, without rip cords, wherein the cable has a "flat" cross section.

DETAILED DESCRIPTION OF A PRESENTLY MOST PREFERRED EMBODIMENT AND BEST MODE OF PRACTICING THE INVENTION

Basic Cable Structures

The cable can be of any conventional design, which includes at least one conductor in a protective jacket. In mining operations, the conductor is typically an electrically conductive material for conducting electricity, preferably copper. Of course, the invention is applicable to fiber-optic cables for conducting optical signals that can also be needed in various harsh environments. The cable typically includes a plurality of conductors intertwined with each other in a generally helical arrangement within the jacket, presenting a circular cross-section. The cable

1 can also be made in what is sometimes referred to as a "flat" design, which is an oblong cross-
2 section created by, for example, three straight and parallel conductors arranged in a row. If
3 desired, an insulating filling material is used to expand and fill in the interstices between the
4 intertwined conductors and the jacket. The jacket helps hold the cable together and provides
5 some of the structural strength and integrity of the cable.

6 The present invention will be described by referring to various examples of how the
7 invention can be made and used. Like reference characters are used throughout the several views
8 of the drawing to indicate like corresponding parts.

9
10 FIGS 1-3

11 Referring to FIGS. 1 and 2, the numeral 10 generally designates a cable assembly. In the
12 illustrated embodiment, the cable assembly 10 includes three helically extending insulated
13 conductors 12, 13, and 14 enclosed in an interior passage 15 of a tubular protective outer cable
14 jacket 16. The insulated conductors 12, 13 and 14 include outer surfaces 17, 18 and 19 and are
15 intertwined together in a helical arrangement forming a plurality of helically extending interstices
16 20, 21, 22 and 23. Interstice 20 is bounded by surfaces 17 and 18 of conductors 12 and 13 and
17 by inner surface 24 of outer jacket 16. Interstice 21 is bounded by outer surfaces 18 and 19 of
18 conductors 13 and 14 and by inner surface 24 of outer jacket 16. Interstice 22 is bounded by
19 surfaces 17 and 19 of conductors 12 and 14 and by inner surface 24 of outer jacket 16. Interstice
20 23 is bounded by surfaces 17, 18 and 19 of conductors 12, 13 and 14.

21 It is common to have fill material 25 is positioned in the interstices 20, 21, 22, and 23 in
22 the cable assembly 10. The fill material can be extruded material, or it can be a fibrous material,
23 such as a plurality of fibrous strand bundles 26, 27, 28, and 29. These fibrous strand bundles can
24 be formed of polymeric materials such as polyacrylate or natural polymeric materials of cellulosic
25 origin. Strand bundles 26, 27, 28, and 29 extend the full length of the cable assembly 10 and are
26 positioned to helically extend in the interstices 20, 21, 22, and 23, respectively. It should be
27 appreciated, however, that other fill material structure can be used, such as tape or powder
28 materials.

29 Each electrical conductor 12, 13 and 14 includes a conductor core 30, 31 and 32 and an
30 insulation layer 33, 34 and 35. Each conductor core 30, 31 and 32 comprises a plurality of copper
31 wire strands 30a, 30b, 31a, 31b, 32a and 32b, respectively. Copper wires 30a, 30b, 31a, 31b, 32a
32 and 32b are preferably annealed copper manufactured in accordance with ASTM Specifications

1 B-3 or B-33. Insulation layers 33, 34 and 35 are preferably made of material such as layers of a
2 silicone rubber impregnated glass tape, GEXOL®, ethylene propylene rubber (EPR), or other
3 chemically cross-linked, thermosetting polyolefin. (In some applications other than mining, such
4 as for shipboard cable, it can be desirable that the polyolefin be flame retardant.)

5 It should be appreciated that the core and individual conductor insulation may vary
6 depending on the application. For instance, in a conventional power cable application, the
7 conductor core is preferably class B, C or D soft or annealed copper (either tinned or bare
8 copper), or class G, H, or I flexible copper (either tinned or bare copper) in accordance with
9 ASTM Specifications B-3 and B-8. A strand shield may be provided which is formed by
10 extruding a semiconducting layer over the conductor core, applied in tandem with and firmly
11 bonded to an insulation layer. The insulation layer is preferably ethylene propylene rubber (EPR)
12 meeting the requirements of the Insulated Cable Engineers Association ("ICEA") standard S-75-
13 381, either Type 1 or Type 2 insulations. (In certain other industrial applications, the
14 Underwriters Laboratories Standard is ULS 1072 for Medium Voltage solid dielectric cable
15 (MV90)). Over the insulation, a semiconducting insulation screen, which meets or exceeds the
16 requirements ICEA S-68-516, is extruded directly over the insulation to form an insulation shield.

17 In telecommunications embodiments, the conductors are either electrical and/or fiber-
18 optic. The electrical conductors in telecommunications applications are preferably solid
19 conductors. The insulation layers for the conductors are preferably made of polypropylene or
20 polyethylene.

21 Although rip cords are not generally used in the mining industry, as best illustrated in FIG.
22 1, one or more rip cords 36a, 36b and 36c, made from a high strength material, can be positioned
23 to extend longitudinally along the interior passage 15 of jacket assembly 16. Preferably, rip cords
24 36a, 36b and 36c extend along and run generally parallel with a longitudinal axis 38 of the cable
25 assembly 10 and are 120° apart positioned on opposed sides of the cable. In the embodiment
26 illustrated in FIGS. 1 and 2, rip cords 36a, 36b and 36c are positioned adjacent the inner surface
27 24 of outer jacket 16 and exteriorly of the insulated conductors 12, 13 and 14 and fill material 25.
28 A binder tape 39 is helically wound around the exterior of the conductors 12, 13 and 14 and fill
29 material 25 and is used for holding the conductors and fill material together during manufacture.
30 A longitudinal positioning (non-helical) of the rip cords is preferred, forming an acute angle with
31 the helical path of the binder tape and fill material. However, the rip cords can be wound in a
32 helical arrangement provided they are positioned exteriorly of the fill material 25.

1 In a second embodiment, illustrated in FIG 3, an easy stripping assembly 100 can be useful
2 in a situation where integral fill is used. Assembly 100 preferably includes three longitudinally
3 extending insulated conductors 112, 113 and 114 enclosed in an interior passage 115 of a tubular
4 protective outer cable jacket 116. The insulated conductors 112, 113 and 114 include outer
5 surfaces 117, 118 and 119 and are intertwined together in a helical arrangement forming a
6 plurality of interstices 120, 121, 122 and 123. Interstice 120 is bounded by surfaces 117 and 118
7 or conductors 112 and 113 and by inner surface 124 of outer jacket 116. Interstice 121 is
8 bounded by outer surfaces 118 and 119 of conductors 113 and 114 and by inner surface 124 of
9 outer jacket 116. Interstice 122 is bounded by surfaces 117 and 119 of conductors 112 and 114
10 and by inner surface 124 of outer jacket 116. Interstice 123 is bounded by surfaces 117, 118 and
11 119 of conductors 112, 113 and 114.

12 To prevent water from traveling down the interstices 120, 121, 122 and 123 in the cable
13 assembly 100, a fill material 125 can be positioned in the interstices 120, 121, 122 and 123.

14 Each electrical conductor 112, 113 and 114 includes a conductor core 130, 131, and 132
15 and an insulation layer 133, 134 and 135. Conductor cores 130, 131 and 132 each comprise a
16 plurality of copper wire strands 130a, 130b, 131a, 131b, 132a and 132b are preferably annealed
17 copper manufactured in accordance with ASTM B-3 or B-33.

18 Preferably, three longitudinally extending rip cords 136a, 136b and 136c are positioned
19 in the interior passage 115 of jacket 116. Rip cords 136a, 136b and 136c extend along and run
20 generally parallel with a longitudinal axis of the cable assembly 100. In the embodiment illustrated
21 in FIG. 3, longitudinally extending rip cords 136a-c are positioned adjacent fill material 125 and
22 conductors 112, 113 and 114. Binder tape 139 is interposed between rip cords 136a-c and inner
23 surface 124 of outer jacket 116. Binder tape 139 is preferably tearable and is helically wound
24 around conductors 112, 113 and 114 and fill material 125 and rip cords 136a, 136b and 136c.

25 26 FIGS. 4-5

27 FIGS. 4 and 5 illustrate presently most-preferred embodiments for mining cable, without
28 rip cords, where FIG. 4 illustrates a mining cable having a circular cross section, and where FIG.
29 5 illustrates a mining cable having a "flat" cross section.

30 Referring to FIG. 4, the cable includes a relatively thin polyurethane sleeve 401, a
31 thermoset jacket 402, a structural reinforcement 403 (such as cotton, polyester, nylon, or any
32 other spun fiber, or fiberglass), a braid shield 404, insulation 405, separator 406 (such as mylar

1 tape), conductor 407, ground check 408, filler 409 (such as jute, an elastomer, polypropylene),
2 and a ground strand 410.

3 Referring to FIG. 5, the "flat" cable includes a relatively thin polyurethane sleeve 501, a
4 thermoset jacket 502, a ground check 503, a core binder 504, an insulated ground 505, insulation
5 506, a conductor shield 507, and a conductor 508.

6 7 Jacket and Urethane-Based Coating

8 According to the invention, the jacketing material of a mining cable preferably is formed
9 of a polymer mixture based on any of the following polymers: Chlorinated Polyethylene (CPE),
10 Chlorosulfonated Polyethylene (CSM), Polychloroprene (CR), or Natural Rubber (NR).

11 According to the invention, a urethane-based coating is provided over the jacket of a
12 cable. The urethane-based coating improves the abrasion resistance of the cable. Urethane
13 polymers are polymers that contain urethane groups, which are also known as carbamate groups,
14 in the backbone of the polymer chain. In general, a linear urethane polymer chain is a
15 thermoplastic material and tends to have good impact strength, good physical properties, and
16 excellent processability, but owing to its thermoplastic characteristic, limited thermal stability.
17 A branched chain or cross-linked polyurethane is a thermoset material and tend to have lower
18 impact strength, but owing to its thermoset characteristic, good thermal stability.

19 20 Thermoplastic Urethane Coating

21 According to a first aspect of the invention, the urethane-based coating is a thermoplastic
22 urethane. The thermoplastic urethane material can be either polyether or polyester based, with
23 polyester being the presently more preferred construction. Suitable thermoplastic urethane
24 coating material can be obtained from commercial suppliers.

25 The thermoplastic urethane sleeve is preferably extruded as a sleeve over a pre-existing
26 jacketed cable. The wall thickness of the thermoplastic urethane sleeve over the cable core can
27 range down to about 0.05 inches (0.13 cm), although it is difficult to extrude a thickness of less
28 than about 0.075 inches (0.2 cm), and 0.100 – 0.125 inches (0.25 - 0.32 cm) is more preferred.
29 For larger cables, the urethane sleeve thickness is preferably about one-third (33%) of the jacket
30 wall thickness.

The thermoplastic urethane sleeve has the following physical property ranges:

Tensile at Break (psi) 3,000 to 8,000, with 4,700 psi nominal preferred
(20 to 55 MPa with 33 MPa nominal preferred);
Elongation at Break (%) 150 to 700 percent, with 400-600 percent preferred;
Durometer Hardness 60 Shore A to 75 Shore D, with 85 to 95 Shore A preferred;

Abrasion Resistance 0.4 to 3.2 mg, more preferably 0.01 to 0.05 cm³ vol. loss.

The abrasion resistance can be measured according to the Taber Abrasion method using 1,000 g wt and 5,000 revolutions, which methodology is well known to those skilled in the art. The abrasion resistance is more preferably measured as volume loss using the method outlined in ISO-4649-1985(E), which employs a 40 meter length of travel and a constant force of 10 Newtons on the sample.

The thermoplastic urethane is preferably extruded over the pre-existing jacketed cable using the following extrusion process parameters:

Extruder (L/D) 15:1 to 32:1, with 24:1 ratio is preferred;
Compression Ratio 2.5:1 to 3.0:1; and
Compound Melt Temperature 330 to 350 °F (165 to 177 °C).

To prevent slippage of the thermoplastic urethane sleeve relative to the cable jacket and core, it is preferable and beneficial to provide a minimal amount of chemical adhesion between the cable core and the thermoplastic urethane sleeve. The desired adhesion levels are in the range of 1.0 to 3.0 pounds per inch force needed to separate the thermoplastic urethane from the cable jacket of the cable. The adhesion is attained by the use of various commercial adhesive products, with cyanoacrylates and epoxy systems being preferred, or urethane based adhesives.

Thermoplastic Urethane Example

This example process utilizes either a polyester or polyether based urethane, which is extruded over an existing jacketed cable. The base cable used in this example process is a 2/0 2kV shielded design. It is to be understood, of course, that other types of cable can be used.

The thermoplastic urethane used in the example was the following ether based resin:

Trade name -	Elastollan 1185A;
Manufacturer -	BASF;
Tensile at Break -	33 Mpa nominal;
Elongation at Break -	640% nominal;
Hardness -	85 shore A; and
Abrasion Resistance -	30 mg, preferably 0.036 cm ³ vol. loss. nominal.

Prior to extrusion, the resin is heat dried to remove any surface moisture present.

A standard thermoplastic extruder with a presently most preferred L/D ratio of at least 24:1 is recommended. Screw designs utilizing a compression ratio of between 2.5:1 and 3.0:1 are recommended. The following extrusion process parameters were used in the experiment:

Extruder L/D -	24/1;
Screw Design -	2.5:1 to 3.0:1 compression ratio; and
Extrudate Temp -	330 to 350 degrees F (165 to 177 °C).

The wall thicknesses of the thermoplastic urethane sleeve can range down to about 0.050 inches (0.13 cm), although it is difficult to extrude a thickness of less than about 0.075 inches (0.2 cm), and 0.100 – 0.125 inches (0.25 - 0.32 cm) is more preferred. For larger cables, the urethane sleeve thickness is preferably about one-third (33%) of the jacket wall thickness.

Prior to coating with the thermoplastic urethane, the jacket of the cable is treated with a suitable bonding agent to provide adhesion between the thermoplastic urethane jacket and the cable. The adhesive is selected so as to activate at the temperatures attained during the extrusion process. According to the example, the type of adhesives used are marketed under the trade names "Chemlok 219" and "Chemlok 250", both commercially available from Lord Chemical.

Thermoset Urethane

According to a second aspect of the invention, a thermoset compound based on a urethane polymer is used to coat the jacket of a cable. This option differs from the thermoplastic urethane in that the urethane coating is a thermoset material.

Advantages of using a thermoset urethane include higher upper temperature resistance and improved bonding of the components. An additional advantage of the thermoset option is that these materials can be custom designed to balance physical properties of the finished material, for

1 example, the urethane covering in this case is a specially compounded material specifically
2 designed to balance abrasion resistance and flexibility to the finished cable.

3 The base compound can be either polyether or polyester based, with the polyester material
4 being preferred. In addition to the polymer, this option also employs the use of various fillers,
5 plasticizers, process aids, and vulcanization systems to attain the desired finished product. Of
6 major importance to the performance of the finished product is the filler system and the
7 vulcanization system of the compound. Typical filler systems for thermoset urethane systems are
8 comprised of carbon black and inorganic mineral fillers.

9 Typical carbon blacks used are categorized as SAF (super abrasion furnace) or HAF (high
10 abrasion furnace), and typically have a particle size ranging from about 1 to about 50 nanometers
11 in size, with from about 20 to about 30 nm being preferred. Typical percentage loading levels are
12 between 10 to 40 percent by weight of the total recipe, with about 20 percent by weight being
13 preferred.

14 Inorganic fillers comprise kaolin (hydrated aluminum silicate), talc (magnesium silicate),
15 or silica (hydrated silica) families, and provide the benefit of non black compounds. The preferred
16 filler system for non-black compound is silica based. Typical silica utilized in this type of recipe
17 range from about 120 to 160 square meters per gram surface area (reinforcement properties of
18 silica are based on the measured surface area), with 150 – 160 range being the preferred material.
19 Typical percentage loading levels are slightly lower than those seen with carbon black systems,
20 and range from 5 to 25 percent of the total recipe. In certain formulations, it is sometimes
21 beneficial to use both black and non-black material to provide a balance of physical, chemical, and
22 processing properties to the finished product – as is well known to those skilled in the art.

23 The thermoset systems can be vulcanized by the use of organic peroxides or sulfur based
24 systems. The preferred method of vulcanization uses organic peroxides.

25 The thermoset urethane coating has the following physical property ranges:

26 Tensile at Break	2,000 to 4,500, with >3,500 psi preferred
27	(14 MPa to 31 MPa, with > 24 MPa preferred):
28 Elongation at Break	150 to 750 %, with 400 to 600 % preferred:
29 Durometer Hardness	40 to 95 Shore A, with 70 to 80 Shore A preferred: and
30 Abrasion Resistance	1.0 to 150 mg, with <100.0 preferred, more preferably
31	0.050 to 0.10 cm ³ volume loss, with <0.08 preferred.

1 The thermoset urethane is preferably co-extruded over the base jacket material and co-
2 vulcanized to produce the finished cable. In the case of neoprene or CSM, the compounded
3 urethane would utilize a sulfur cure system to attain the desired level of composite properties.
4 In the case of a CPE substrate, the urethane would employ a peroxide cure system for adhesion.

5 The product is to be manufactured on a typical lead line. For example, the first tuber
6 extrudes the jacket substrate, i.e., neoprene, CPE, or CSM. Wall thicknesses of this extrusion
7 would preferably account for approximately two-thirds (67%) of the finished cable diameter of
8 the product. The second tuber extrudes a specially designed urethane compound over the
9 substrate, preferably comprising approximately one-third (33%) of the jacket wall thickness.

10 The following are expected to be the preferred extrusion process parameters:

11 Extruder (L/D)	15:1 to 24:1, with 15:1 preferred;
12 Compression ratio	1.5:1 to 2.5:1, with 1.5:1 preferred; and
13 Compound Melt Temperature	140 to 270 degrees F (60 to 132 °C),
14	preferably 165 to 185 degrees F (74 to 85 °C).

15 After application of the jackets, the cable is preferably water cooled, then immediately run
16 through the lead extruder. The internal diameter of the lead extrusion would be set at about 96%
17 of the cable outer diameter with a wall thickness of about 0.2 inches (0.5 cm). The finished
18 construction is then be placed in an autoclave, and the cable cured.

19 Typical wall thicknesses of the urethane coating can vary from at least 0.050 inches, and
20 for larger cable about one-third (33%) the thickness of the jacket being the presently most
21 preferred. Due to the cross linked nature of this polymer, thinner wall thickness of the urethane
22 coating is desirable.

23 Due to the process of co-extruding the thermoset urethane over the non-vulcanized
24 jacketing material, and co-curing the combination, adhesive systems are not necessary with the
25 thermoset urethane coating.

27 Scope of Invention Not Limited to Preferred Embodiments

28 The invention is described with respect to presently preferred embodiments, but is not
29 intended to be limited to the described embodiments. It will be readily apparent to one of
30 ordinary skill in the art that numerous such modifications may be made to the invention without
31 departing from the spirit and scope of it as claimed.

International Standard

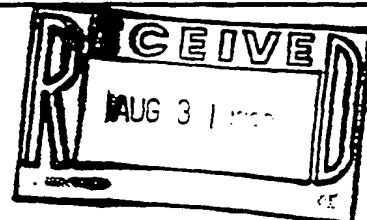


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Rubber — Determination of abrasion resistance using a rotating cylindrical drum device

Caoutchouc — Détermination de la résistance à l'abrasion à l'aide d'un dispositif à tambour tournant

First edition — 1985-04-01

APPENDIX A (10 pages)

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Ref. No. ISO 4649-1985 (E)

Descriptors : rubber, vulcanized rubber, tests, wear tests, abrasion tests, test equipment.

INTERNATIONAL STANDARD

ISO 4649-1985 (E)

Rubber — Determination of abrasion resistance using a rotating cylindrical drum device

1 Scope and field of application

This International Standard specifies a method for the determination of the resistance of rubber to abrasion by means of a rotating cylindrical drum device.

The method involves determination of the volume loss of a rubber test piece through abrasive action by rubbing over a specified grade of abrasive cloth. Because factors such as the grade of abrasive particles and adhesive used in the manufacture of the cloth, and contamination and wear by previous testing, lead to variations in the absolute values of abrasion loss, all tests must be comparative, standard rubbers being included so that the results may be expressed either as a relative volume loss referred to a calibrated abrasive cloth or an abrasion resistance index referred to a standard rubber.

No close relation between the results of this abrasion test and service performance can be inferred.

2 References

ISO 48, *Vulcanized rubbers — Determination of hardness (Hardness between 30 and 85 IRHD)*.

ISO/R 275, *Zinc oxide for paints*.

ISO 471, *Rubber — Standard temperatures, humidities and times for the conditioning and testing of test pieces*.

ISO 2393, *Rubber test mixes — Preparation, mixing and vulcanization — Equipment and procedures*.

ISO 2781, *Vulcanized rubber — Determination of density*.

ASTM D 1765, *Standard classification system for carbon blacks used in rubber products*.

3 Principle

Subjection of a cylindrical rubber test piece to the action of an abrasive cloth of specified abrasive grade at a specified contact pressure over a given area.

Abrasion takes place over one of the flat end surfaces of the cylindrical test piece, the abrasive cloth being attached to the surface of a rotating cylindrical drum against which the test piece is held and across which it is traversed.

Determination of the loss in mass of the test piece and calculation of the volume loss from the density of the material.

4 Definitions

For the purposes of this International Standard, the following definitions apply.

4.1 abrasion resistance: The resistance to wear by mechanical action upon a surface.

NOTE — For the purpose of this International Standard, the abrasion resistance is expressed either as a relative volume loss referred to a calibrated abrasive cloth or as an abrasion resistance index referred to a standard rubber.

4.2 relative volume loss: The volume loss, in cubic millimetres, of the test rubber after being subjected to abrasion by an abrasive cloth will cause the appropriate standard rubber (see clause B.1 in annex B) to lose a mass of 200 mg under the preferred conditions of test for method A, namely a distance of 40 m, a load of 10 N and using a non-rotating test piece.

NOTE — The higher the relative volume loss, the lower is the abrasion resistance.

4.3 abrasion resistance index: The ratio of the volume loss of a standard rubber to the volume loss of the test rubber measured under the same specified conditions and expressed as a percentage.

5 Apparatus and materials

5.1 Abrasion machine

The test apparatus (see figure 1) consists of a laterally movable test piece holder and a rotatable cylinder to which the abrasive cloth (5.2) is fixed.

The cylinder shall have a diameter of $150 \pm 0,2$ mm and a length of about 500 mm and shall be rotated at a frequency of 40 ± 1 min⁻¹, the directions of rotation being as indicated in figure 1.

The test piece holder shall consist of a cylindrical opening, the diameter of which can be adjusted from 15,5 to 16,3 mm, and a device for adjusting the length of the test piece protruding from the opening to $2 \pm 0,2$ mm. The holder shall be mounted on a swivel arm which in turn is attached to a sledge which can be moved laterally on a spindle. The lateral displacement of the holder shall be $4,20 \pm 0,04$ mm per revolution of the drum. Suitable attachments may be provided to rotate the test piece during the test run by rotation of the test piece holder preferably, at the rate of 1 revolution per 50 revolutions of the drum.

NOTE — With this lateral movement, the test piece passes over any one area of the abrasive cloth four times.

The centre axis of the holder shall have an inclination of 3° to the perpendicular in the direction of rotation (see figure 1), and shall be placed directly above the longitudinal axis of the cylinder to within ± 1 mm.

The swivel arm and test piece holder shall be free from vibration during operation, and so disposed that the test piece is pressed against the drum with a vertical force of 10 ± 0.2 N obtained by adding weights to the top of the test piece holder. For special purposes a force of 5 ± 0.1 N may be used.

The abrasive cloth shall be attached to the drum using three evenly spaced strips of double-sided adhesive tape extending along the complete length of the cylinder. Care shall be taken to ensure that the abrasive cloth is firmly held so as to present a uniform abrasive surface over the whole area of the cylinder. One of the strips shall be placed where the ends of the abrasive cloth meet. Ideally the ends should meet exactly, but any gap left between them shall not exceed 2 mm. The adhesive tape shall be about 50 mm wide and not more than 0.2 mm thick.

Placement of the test piece on to the cloth at the beginning of a test run, and its removal after an abrasion run of 40 m (equivalent to 84 revolutions), shall be automatic. In special cases of very high volume loss of the test piece, an abrasion distance of only 20 m (equivalent to 42 revolutions) may be used. If using an abrasion distance of 20 m, a revolution counter or automatic stopping device should be connected to the drum.

To protect the abrasive cloth from damage by the test piece holder, a device for switching off the apparatus just before the lower edge of the test piece holder touches the cloth is recommended.

5.2 Abrasive cloth

Abrasive cloth made with aluminium oxide of grain size 60, at least 400 mm wide, 473 mm long and 1 mm average thickness, shall be used as the abrasive medium.

In a test using a non-rotating test piece of the standard rubber described in annex B, clause B.1, this abrasive surface shall cause a mass loss between 180 and 220 mg for an abrasion distance of 40 m.

When each new sheet of cloth is first used, the direction of motion shall be indicated on the sheet, as it is important that the same direction be used for all subsequent test runs.

Notes on a suitable paper are given in annex A.

5.3 Hollow drill (see figure 2)

The drill may be required for preparation of test pieces (see 6.1). The frequency of rotation of the drill needs to be at least $1\,000\text{ min}^{-1}$ for most rubbers, and even higher for rubbers with a hardness of less than 50 IRHD (see ISO 48).

5.4 Balance

The balance shall be of sufficient accuracy to enable the mass loss of a test piece to be determined to ± 1 mg.

5.5 Standard rubbers

Specifications for standard rubbers are given in detail in annex B.

6 Test piece

6.1 Type and preparation

The test pieces shall be cylindrical in shape, of diameter 16 ± 0.2 mm, with a minimum height of 6 mm.

Test pieces are normally prepared using the hollow drill (5.3). During cutting, the cutting edge should be lubricated with water to which a wetting agent has been added. Punching of the test pieces is not permitted.

Alternatively, test pieces may be vulcanized in a mould.

If test pieces of the required thickness are not available, the necessary thickness may be obtained by bonding a piece of the test rubber to a base element of hardness not less than 80 IRHD. The thickness of the test rubber should be not less than 2 mm.

6.2 Number

Three test runs shall be carried out. This will normally require three test pieces, but only one test piece may be necessary if the mass loss per run is very low.

6.3 Time interval between vulcanization and testing

For all test purposes, the minimum time between vulcanization and testing shall be 16 h. For non-product tests, the maximum time between vulcanization and testing shall be 4 weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time interval. For product tests, whenever possible, the time between vulcanization and testing shall not exceed 3 months. In other cases, tests shall be made within 2 months of the date of receipt of the product by the customer.

6.4 Conditioning

Condition all test pieces, at standard laboratory temperature, in accordance with ISO 471, for a minimum period of 16 h immediately before testing.

NOTE — For some rubbers which are sensitive to moisture, the humidity should also be controlled.

7 Test temperature

The test shall be carried out at standard laboratory temperature (see ISO 471).

During a test run, there may be a considerable increase in temperature at the abrading interface, which may lead to temperature rises within the test piece. For the purposes of this International Standard, such temperature rises are to be disregarded, the temperature of test being that of the ambient atmosphere and of the test piece before commencing the test.

When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature.

8 Procedure

8.1 General test procedure

Before each test, any rubber debris left on the abrasive cloth from a previous abrasion test shall be removed with a brush. A strong brush of about 55 mm diameter and about 70 mm length is recommended for this purpose. In some cases, a blank test with a standard rubber will effectively clean the abrasive cloth.

The test run may be carried out with the test piece either rotating or stationary (non-rotating). For method A (9.1) the non-rotating test piece shall be used. For method B (9.2) the rotating test piece is preferred but the non-rotating test piece may also be used. The test piece used shall be stated in the test report, because the results obtained by these two procedures can differ. For measurements intended to be comparable, the same conditions shall be used.

Weigh the test piece to the nearest 1 mg. Fix the test piece in the test piece holder in such a way that a length of 2.0 ± 0.1 mm protrudes from the opening. This length shall be controlled by means of a gauge.

The test piece should be pressed against the drum with a vertical force of 10 ± 0.2 N. If, for special cases, the vertical force is reduced to 5 ± 0.1 N, this shall be stated in the test report because the severity of abrasion is lower.

Move the test piece holder and sledge to the starting point, place the test piece on the abrasive cloth and set the cylinder in motion. Check for vibration in the test piece holder. This test method does not yield meaningful results if there is abnormal vibration in the test piece holder. The test run is stopped automatically after an abrasion distance of 40 m. When relatively large mass losses (usually more than 400 mg in 40 m) occur, the test run may be stopped after 20 m, and the length of exposed test piece reset to 2.0 ± 0.2 mm so that the test can be restarted and completed. At no time shall the height of the test piece be less than 5 mm. If the mass loss is greater than 600 mg in 40 m, the test should only be carried out for half distance (i.e. 20 m) and this should be stated in the test report. The results should be multiplied by 2 so that the mass loss can still be given for an abrasion distance of 40 m.

Weigh the test piece to the nearest 1 mg after the test run. Sometimes a small edge hanging from the test piece has to be pulled off before weighing, especially if a non-rotating test piece is used.

Perform three test runs on each rubber under test. Normally only one run per test piece is carried out, but if the mass loss is relatively small, up to three test runs can be carried out on the same test piece. When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature. For non-rotating test pieces, care shall be taken to ensure that the test piece is always placed in the sample holder in the same way. If a series of rubbers is being tested, all three test runs on the same rubber shall be carried out consecutively.

8.2 Density

Determine the density of the test material by the method specified in ISO 2781.

8.3 Comparison against standard rubbers

In this International Standard, the test rubbers are compared against standard rubbers. Two standard rubbers are specified in annex B for use with the two methods of expressing results (see clause 9). That specified in clause B.1 is intended for use in method A, where the abrasion resistance is expressed as relative volume loss ΔV (see 9.1). That specified in clause B.2 is intended for use in method B, where the abrasion resistance is expressed as an abrasion resistance index, ARI (see 9.2).

The mass loss of a standard rubber shall be determined by carrying out a minimum of three test runs both before and after each test series following the procedure in 8.1. There shall be a maximum of three test rubbers in each test series.

For rubbers which have a tendency to smear, the mass loss of the standard rubber shall be determined after each test run. In extreme cases of smearing, there will be a considerable reduction in mass loss of the standard rubber measured after the test run compared to that measured before the test run. This is due to the fact that in the test run, the abrasive cloth is being "cleaned" by the standard rubber, as opposed to the standard rubber being abraded by the cloth. If the reduction in mass loss of the standard rubber is greater than 10 %, then the method is not valid.

9 Expression of results

The results may be expressed either as a relative volume loss (method A — see 9.1) or as an abrasion resistance index (method B — see 9.2).

Calculate the mean value of the mass losses of the test rubber m_t , and of the standard rubber, m_s , from the three and six separate determinations respectively.

Calculate the volume losses of the test rubber, V_t , and of the standard rubber, V_s (for method B only), from the respective mass losses and densities.

9.1 Method A — Relative volume loss, ΔV

In this method, the standard rubber specified in clause B.1 in annex B is used. The non-rotating test piece shall be used for both the test rubber and the standard rubber. The measured mass loss of the standard rubber using a non-rotating test piece shall be within the range 180 to 220 mg.

The relative volume loss (see 4.2) is given by the formula

$$\Delta V = V_t \times \frac{200}{m_s}$$

where

V_t is the volume loss, in cubic millimetres, of the test rubber;

m_s is the mass loss, in milligrams, of the standard rubber (clause B.1) using a non-rotating test piece.

NOTE — The non-rotating test piece is used because of the considerable experience obtained previously with this method using the non-rotating test piece.

9.2 Method B — Abrasion resistance index, ARI

In this method, the standard rubber specified in clause B.2 in annex B is used. The same type of test piece (rotating or non-rotating) shall be used for both the test rubber and the standard rubber.

The abrasion resistance index (see 4.3) is given by the formula

$$ARI = \frac{V_s}{V_t} \times 100$$

where

V_s is the volume loss, in cubic millimetres, of the standard rubber (clause B.2);

V_t is the volume loss, in cubic millimetres, of the test rubber.

NOTE — The rotating test piece is the preferred test piece because the abrasion loss is more uniform over the whole surface of the test piece in contact with the abrasive cloth.

10 Test report

The test report shall include the following particulars :

a) sample details :

- 1) full description and origin,
- 2) compound details, cure time and temperature, if available,
- 3) method of preparation of the test pieces from the sample, i.e. whether cut or moulded;

b) test method : reference to this International Standard;

c) test details :

- 1) standard laboratory temperature used,
- 2) whether a non-rotating or rotating test piece was used,
- 3) type of standard rubber used,
- 4) any deviations from the test procedure, especially if the test run comprised only half the abrasion distance or if half the vertical force was used;

d) test result :

- 1) either the relative volume loss or the abrasion resistance index,
- 2) standard deviation of test result,
- 3) density;

e) date of test.

Annex A

Notes on a suitable abrasive cloth

(Forms an integral part of the Standard.)

A suitable abrasive cloth is produced commercially¹⁾. It comprises corundum particles of grain size 60, i.e. passing through a 60 mesh sieve, bonded to a twill cloth with a phenolic resin. As produced, the abrasive cloth causes an abrasion loss of more than 300 mg when the standard rubber specified in annex B, clause B.1, is tested using a non-rotating test piece. It is necessary to perform one or two runs with a steel test piece to reduce the abrasive loss to about 210 to 220 mg. Experience

has shown that a minimum of a few hundred runs can be carried out with this type of cloth.

Abrasive cloth produced and standardized in this manner may be obtained from the Bundesanstalt für Materialprüfung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de contrôle du caoutchouc (LRCC), 12, rue Carvès, F-92120 Montrouge, France.

¹⁾ Details may be obtained from the Secretariat of ISO/TC 45 (BSI) or from ISO Central Secretariat.

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Annex B

Standard rubbers

(Forms an integral part of the Standard.)

B.0 Introduction

The use of a standard rubber is intended to minimize the variation in abrasion resistance found between laboratories and between machines operating under nominally identical conditions.

The composition and methods of manufacture of the standard rubbers described below are to be taken as a guide; other formulations may be used provided that they fulfil the requirements given in B.1.5 and B.2.4. The standard rubber described in clause B.1 shall be used for the calibration of the abrasive cloth (5.2) and for the calculation of the relative volume loss, ΔV (see 9.1). The standard rubber described in clause B.2 shall be used for the determination of the abrasion resistance index (see 9.2).

B.1 Standard rubber for the determination of relative volume loss, ΔV

B.1.1 Formulation of standard rubber

Ingredient	Parts by mass
Natural rubber (SMR 5)	100.0
Dibenzthiazyl disulfide	1.2
<i>N</i> -isopropyl- <i>N'</i> -phenyl- <i>p</i> -phenylenediamine	1.0
Zinc oxide (type 1; see ISO/R 275)	50.0
Oil furnace black (N330-HAF1)*	36.0
Sulfur	2.5
TOTAL	190.7

* See ASTM D 1765.

B.1.2 Mixing procedure

The following procedure is recommended.

Masticate the natural rubber to a Mooney viscosity, ML (1 + 4) at 100 °C, of 80 ± 5 , using a mixing mill which complies with the requirements specified in ISO 2393. Then prepare the mix in an internal mixer. Cool the internal mixer to maintain the temperature at 50 ± 5 °C.

	Time (min)
Add the rubber	0
Add the accelerator, antioxidant and zinc oxide	5
Add the carbon black and sulfur	8
Discharge	30

Sheet out the mix on an open mill to a thickness of about 10 mm and check the batch mass.

NOTE — Other mixing procedures may be used provided the quality of the standard rubber produced meets the requirements of B.1.5.

B.1.3 Vulcanization

Bring the mould to the vulcanization temperature and then insert an unvulcanized piece of mix which has been pre-heated for 20 min at 70 °C. An excess of approximately 10 % is recommended. Vulcanize in a closed press at 150 ± 2 °C for 30 ± 1 min, using a moulding pressure of 3.5 MPa.

Sheets measuring approximately 180 mm × 120 mm × 8 mm will provide about 65 test pieces.

B.1.4 Storage

Store the standard sheets in a cool, dark place and wrap them with materials which protect the sheets from attack by ozone (for example polyethylene).

B.1.5 Quality

Each batch of the standard rubber should be compared to a "reference sheet" obtainable from the Bundesanstalt für Materialprüfung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de contrôle du caoutchouc (LRCC), 12, rue Carvès, F-92120 Montrouge, France, using an abrasive cloth prepared in accordance with annex A.

The quality of the standard rubber shall be examined by determining the abrasion resistance of a test piece taken from a corner of the sheet, measured using a non-rotating test piece as described in this International Standard, and then comparing this mass loss with the mean mass loss of a "reference sheet" in immediate consecutive tests. The differences between the mass losses shall not exceed 8 mg.

A standard rubber sheet shall be considered to be a reference sheet if the mass losses measured at six different places (four at the corners and two in the middle) differ by not more than 10 mg and the mean value differs by not more than 5 mg from the mean value of six single values of another reference sheet.

NOTE — It is permitted to carry out three test runs on the same test piece.

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B.2 Standard rubber for the determination of abrasion resistance index, ARI**B.2.1 Formulation of standard rubber**

Ingredient	Parts by mass
Natural rubber (SMR 5)	100.0
Stearic acid	2.0
Zinc oxide	5.0
Oil furnace black (N 330-HAF)*	50.0
<i>N</i> -isopropyl- <i>N'</i> -phenyl- <i>p</i> -phenylenediamine	1.0
Cyclohexyl-benzothiazole sulfenamide	0.5
Sulfur	2.5
TOTAL	161.0

* See ASTM D 1765. For referee purposes, the current industry Reference Black should be used, but this may give slightly different results.

B.2.2 Mixing and vulcanization

The equipment and procedures used for preparation, mixing and vulcanization shall be in accordance with the relevant re-

quirements of ISO 2393; an internal mixer may be used, however, instead of the mixing mill specified in ISO 2393. Sheets shall be vulcanized at 140 °C for 60 min.

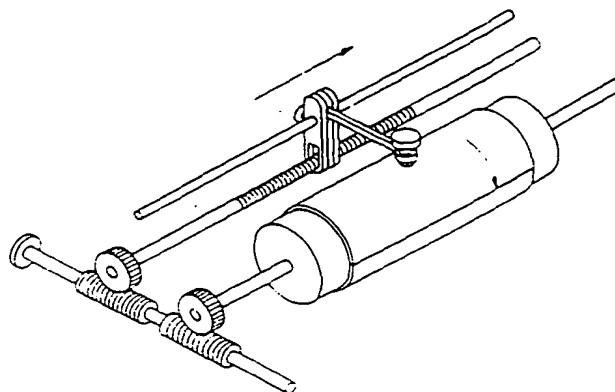
B.2.3 Storage

Store the standard sheets in a cool, dark place and wrap them with materials which protect the sheets from attack by ozone (for example polyethylene).

B.2.4 Quality

The mass losses for two different batches of standard rubber, determined in accordance with clause 8, shall agree to within $\pm 10\%$.

NOTE — It has been found that the standard rubber gives an abrasion loss of about 150 mg when tested in accordance with clause 8, using a rotating test piece.



Dimensions in millimetres

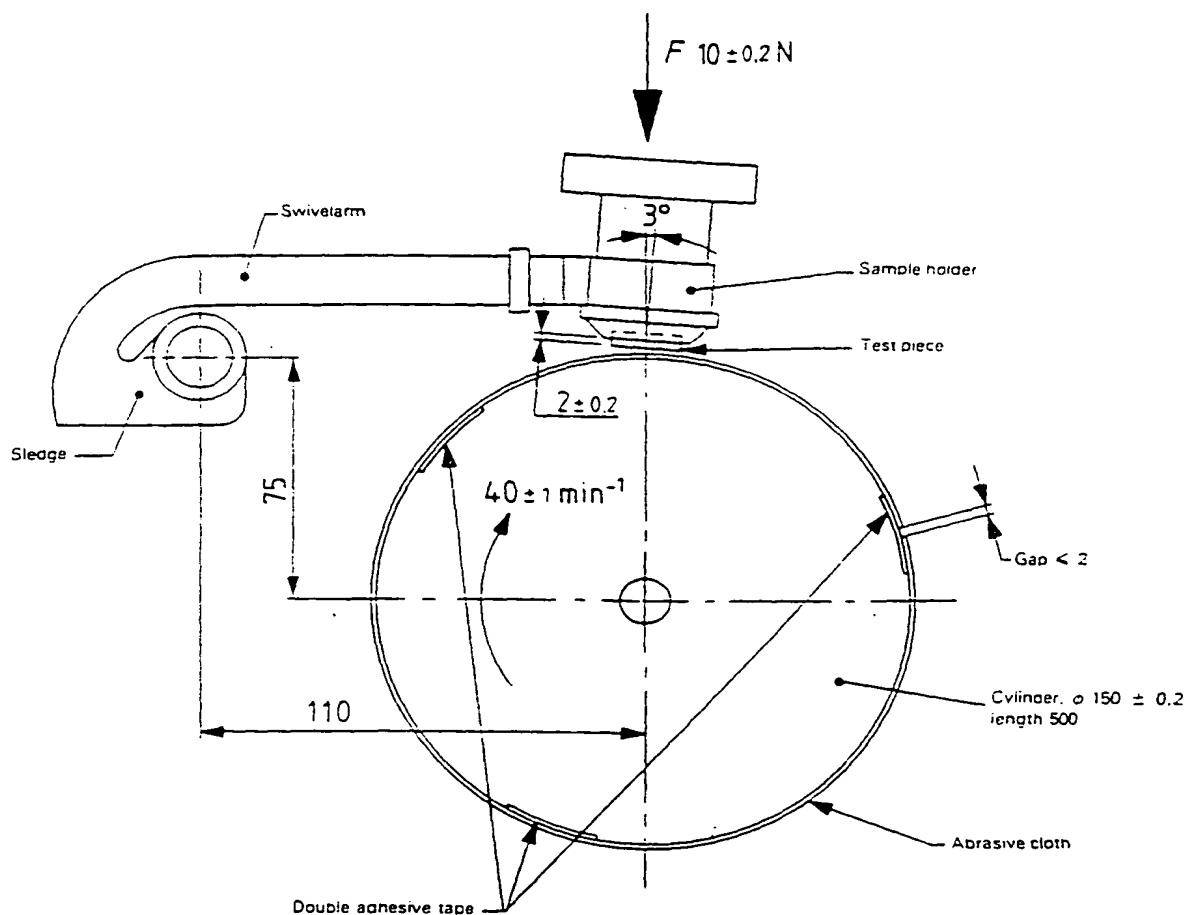


Figure 1 — Schematic illustration of apparatus

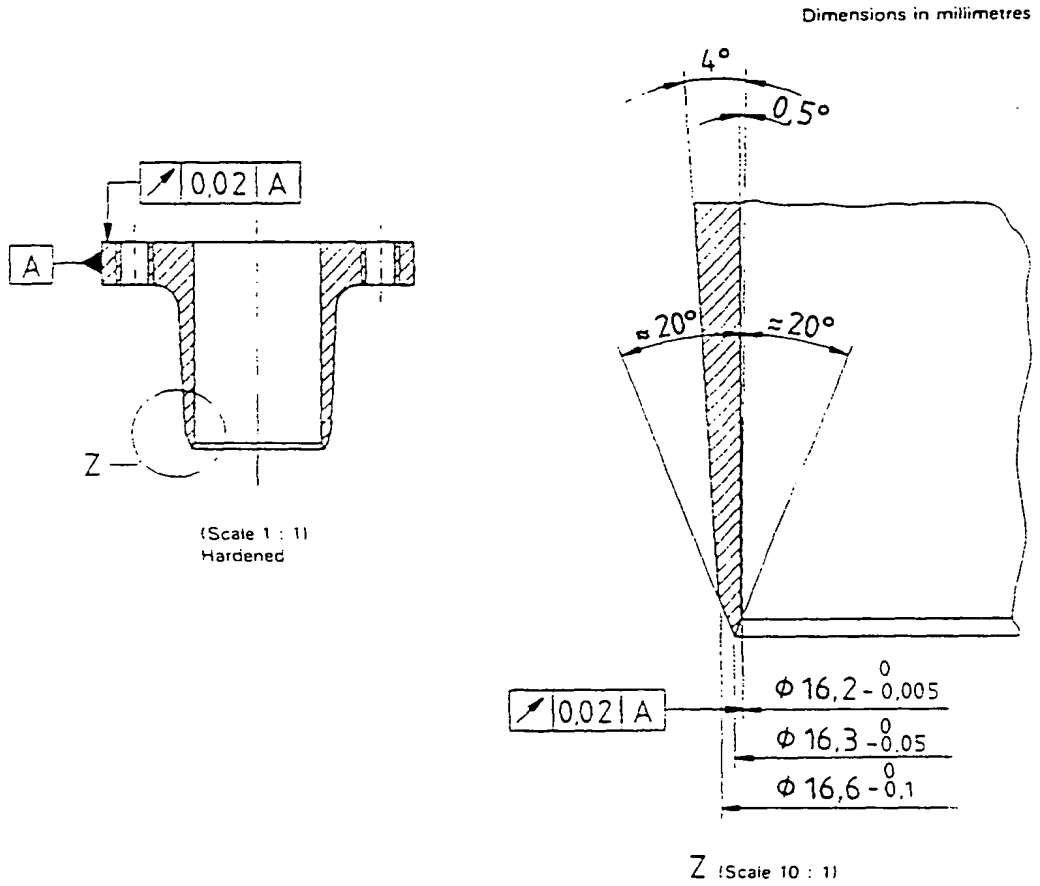


Figure 2 — Hollow drill for test piece preparation

What is claimed is:**COATED CABLE**

- 1 1. A cable for harsh and abrasive environments, the cable comprising:
2 (a) at least one conductor within a jacket; and
3 (b) a urethane-based coating over the jacket.
- 1 2. The cable according to Claim 1, wherein the jacket comprises a material selected
2 from the group consisting of: Chlorinated Polyethylene, Chlorosulfonated Polyethylene,
3 Polychloroprene, or Natural Rubber.

Thermoplastic Material

- 1 3. The cable according to Claim 1, wherein the urethane-based coating is a
2 thermoplastic material.
- 1 4. The cable according to Claim 3, wherein the thermoplastic material is polyether
2 based.
- 1 5. The cable according to Claim 3, wherein the thermoplastic material is polyester
2 based.
- 1 6. The cable according to Claim 3, wherein the thermoplastic material is extruded
2 over a pre-existing jacket on the cable.
- 1 7. The cable according to Claim 3, wherein the wall thickness of the coating is at least
2 0.13 cm.
- 1 8. The cable according to Claim 7, wherein the wall thickness of the coating is about
2 one third (33%) of the thickness of the jacket.
- 1 9. The cable according to Claim 3, wherein the thermoplastic material has a tensile
2 strength at break in the range of 20 to 55 MPa.

1 10. The cable according to Claim 9, wherein the thermoplastic material has a tensile
2 strength at break of about 32 Mpa nominal.

1 11. The cable according to Claim 3, wherein the thermoplastic material has elongation
2 at break in the range of 150 to 700 percent.

1 12. The cable according to Claim 9, wherein the thermoplastic material has elongation
2 at break in the range of 400 to 600 percent.

1 13. The cable according to Claim 3, wherein the thermoplastic material has durometer
2 hardness in the range of 60 Shore A to 75 Shore D.

1 14. The cable according to Claim 13, wherein the thermoplastic material has
2 durometer hardness in the range of 85 Shore A to 95 Shore A.

1 15. The cable according to Claim 3, wherein the thermoplastic material has an abrasion
2 resistance in the range of 0.01 to 0.05 cm³ volume loss measured using the method outlined in
3 ISO-4649-1985(E).

1 16. The cable according to Claim 3, wherein the thermoplastic material has: a tensile
2 strength at break in the range of 20 to 55 MPa; an elongation at break in the range of 150 to 700
3 percent; a durometer hardness in the range of 60 Shore A to 75 Shore D; and abrasion resistance
4 in the range of 0.01 to 0.05 cm³ volume loss measured using the method outlined in ISO-4649-
5 1985(E).

1 17. The cable according to Claim 16, wherein the thermoplastic material has: a tensile
2 strength at break of 32 nominal MPa; an elongation at break in the range of 400 to 600 percent;
3 and a durometer hardness in the range of 85 Shore A to 95 Shore A.

1 18. The cable according to Claim 3, further comprising an adhesive between the jacket
2 and the thermoplastic material.

1 19. The cable according to Claim 18, wherein the adhesive comprises a material
2 selected from the group consisting of: cyanoacrylates and epoxy systems.

Thermoset Material

1 20. The cable according to Claim 1, wherein the urethane-based coating is a thermoset
2 material.

1 21. The cable according to Claim 20, wherein the thermoset material is polyether
2 based.

1 22. The cable according to Claim 20, wherein the thermoset material is polyester
2 based.

1 23. The cable according to Claim 20, wherein the thermoset material is co-extruded
2 with the jacket.

Thermoset Material with Filler System

1 24. The cable according to Claim 20, wherein the thermoset material further comprises
2 a filler system selected from the group consisting of: carbon black, non-black inorganic filler, and
3 any combination thereof.

1 25. The cable according to Claim 24, wherein the carbon black has a particle size
2 range from about 1 to about 50 nanometers.

1 26. The cable according to Claim 25, wherein the carbon black has a particle size
2 range from about 20 to about 30 nanometers.

1 27. The cable according to Claim 24, wherein the carbon black comprises in the range
2 of 10 to 40 percent by weight of the thermoset material.

1 28. The cable according to Claim 27, wherein the carbon black comprises about 20
2 percent by weight of the thermoset material.

1 29. The cable according to Claim 24, wherein the non-black inorganic filler is selected
2 from the group consisting of: kaolin, talc, silica, and any combination of the foregoing.

1 30. The cable according to Claim 29, wherein the non-black inorganic filler is silica.

1 31. The cable according to Claim 30, wherein the silica has in the range of about 120
2 to about 160 square meters per gram surface.

1 32. The cable according to Claim 31, wherein the silica has in the range of about 150
2 to about 160 square meters per gram surface.

1 33. The cable according to Claim 29, wherein the non-black inorganic filler comprises
2 in the range of 5 to 25 percent by weight of the thermoset material.

Thermoset Vulcanization

1 34. The cable according to Claim 20, wherein the thermoset material is vulcanized
2 using organic peroxides.

Thermoset Material Properties

1 35. The cable according to Claim 20, wherein the thermoset material has a tensile
2 strength at break in the range of 14 Mpa to 31 MPa.

1 36. The cable according to Claim 35, wherein the thermoset material has a tensile
2 strength at break of > 24 MPa nominal.

1 37. The cable according to Claim 20, wherein the thermoset material has elongation
2 at break in the range of 150 to 750 percent.

1 38. The cable according to Claim 37, wherein the thermoset material has elongation
2 at break in the range of 400 to 600 percent.

1 39. The cable according to Claim 20, wherein the thermoset material has durometer
2 hardness in the range of 40 Shore A to 95 Shore A.

1 40. The cable according to Claim 39, wherein the thermoset material has durometer
2 hardness in the range of 70 Shore A to 80 Shore A.

1 41. The cable according to Claim 20, wherein the thermoset material has an abrasion
2 resistance in the range of 0.050 to 0.10 cm³ volume loss measured using the method outlined in
3 ISO-4649-1985(E).

1 42. The cable according to Claim 20, wherein the thermoset material has an abrasion
2 resistance of less than 0.08 cm³ volume loss measured using the method outlined in ISO-4649-
3 1985(E).

1 43. The cable according to Claim 20, wherein the thermoset material has: a tensile
2 strength at break in the range of 14 Mpa to 31 MPa; an elongation at break in the range of 150
3 to 750 percent; a durometer hardness in the range of 40 Shore A to 95 Shore A; and abrasion
4 resistance in the range of 0.050 to 0.10 cm³ volume loss measured using the method outlined in
5 ISO-4649-1985(E).

1 44. The cable according to Claim 43, wherein the thermoset material has: a tensile
2 strength at break of greater than 24 Mpa nominal; an elongation at break in the range of 400 to
3 600 percent; a durometer hardness in the range of 70 Shore A to 80 Shore A.

Cable Structure

1 45. The cable according to Claim 20, wherein the wall thickness of the coating is at
2 least 0.13 cm.

1 46. The cable according to Claim 45, wherein the wall thickness of the coating is about
2 one-third the thickness of the jacket.

1 47. The cable according to Claim 1, wherein the conductor is an electrically conductive
2 material for conducting electricity.

1 48. The cable according to Claim 1, wherein the conductor is a fiber-optic conductor
2 for conducting optical signals.

1 49. The cable according to Claim 1, further comprising: a plurality of conductors
2 intertwined with each other in a generally helical arrangement within the jacket.

1 50. The cable according to Claim 49, further comprising a filling material that fills the
2 interstices between the intertwined plurality of conductors.

THERMOPLASTIC PROCESS

1 51. A process of coating a cable adapted for harsh and abrasive environments, the
2 process comprising the steps of:

- 3 (a) selecting a urethane-based coating that is a thermoplastic material; and
4 (b) extruding a thermoplastic urethane-based coating over a pre-existing jacketed
5 cable.

1 52. The process according to Claim 51, wherein the pre-existing jacket comprises a
2 material selected from the group consisting of: Chlorinated Polyethylene, Chlorosulfonated
3 Polyethylen, Polychloroprene, or Natural Rubber.

1 53. The process according to Claim 51, wherein the thermoplastic material is polyether
2 based.

1 54. The process according to Claim 51, wherein the thermoplastic material is polyester
2 based.

1 55. The process according to Claim 3, wherein the wall thickness of the coating is at
2 least 0.13 cm.

1 56. The process according to Claim 55, wherein the wall thickness of the coating is
2 about one-third the thickness of the jacket.

1 57. The process according to Claim 51, wherein the thermoplastic material has a
2 tensile strength at break in the range of 20 to 55 MPa.

1 58. The process according to Claim 57, wherein the thermoplastic material has a
2 tensile strength at break of 33 MPa nominal.

1 59. The process according to Claim 51, wherein the thermoplastic material has
2 elongation at break in the range of 150 to 700 percent.

1 60. The process according to Claim 59, wherein the thermoplastic material has
2 elongation at break in the range of 400 to 600 percent.

1 61. The process according to Claim 51, wherein the thermoplastic material has
2 durometer hardness in the range of 60 Shore A to 75 Shore D.

1 62. The process according to Claim 61, wherein the thermoplastic material has
2 durometer hardness in the range of 85 Shore A to 95 Shore A.

1 63. The process according to Claim 62, wherein the thermoplastic material has an
2 abrasion resistance in the range of 0.01 to 0.05 cm³ volume loss measured using the method
3 outlined in ISO-4649-1985(E)..

1 64. The process according to Claim 51, wherein the thermoplastic material has: a
2 tensile strength at break in the range of 20 to 55 MPa; an elongation at break in the range of 150
3 to 700 percent; a durometer hardness in the range of 60 Shore A to 75 Shore D; and abrasion
4 resistance in the range of 0.01 to 0.05 cm³ volume loss measured using the method outlined in
5 ISO-4649-1985(E).

1 65. The process according to Claim 64, wherein the thermoplastic material has: a
2 tensile strength at break of 33 MPa nominal; an elongation at break in the range of 400 to 600
3 percent; a durometer hardness in the range of 85 Shore A to 95 Shore A.

1 66. The process according to Claim 51, further comprising the step of: applying an
2 adhesive between the jacket and the thermoplastic material.

1 67. The process according to Claim 66, wherein the adhesive comprises a material
2 selected from the group consisting of: cyanoacrylates and epoxy systems.

1 68. The process according to Claim 51, wherein the extrusion process parameters are:
2 the extruder (L/D) is in the range of 15:1 to 32:1; the compression ratio is in the range of 2.5:1
3 to 3.0:1; and the thermoplastic melt temperature is in the range of 165 to 177 °C

Product by Process

1 69. The cable produced according to the process of any one of Claims 51-68.

THERMOSET PROCESS

1 70. A process of coating a cable cable for use in harsh and abrasive environments, the
2 coating process comprising the steps of:

- 3 (a) selecting a urethane-based coating that is a thermoset material; and
- 4 (b) co-extruding the thermoset material with the jacket material over at least one
5 electrical conductor to form a jacketed cable having a urethane-based coating on
6 the outside of the jacket.

1 71. The process according to Claim 70, wherein the jacket material comprises a
2 material selected from the group consisting of: Chlorinated Polyethylene, Chlorosulfonated
3 Polyethylene, Polychloroprene, or Natural Rubber.

1 72. The process according to Claim 70, wherein the thermoset material is polyether
2 based.

1 73. The process according to Claim 70, wherein the thermoset material is polyester
2 based.

Thermoset Material with Filler System

1 74. The process according to Claim 70, wherein the thermoset material further
2 comprises a filler system selected from the group consisting of: carbon black, non-black inorganic
3 filler, and any combination thereof.

1 75. The process according to Claim 74, wherein the carbon black has a particle size
2 range from about 1 to about 50 nanometers.

1 76. The process according to Claim 75, wherein the carbon black has a particle size
2 range from about 20 to about 30 nanometers.

1 77. The process according to Claim 74, wherein the carbon black comprises in the
2 range of 10 to 40 percent by weight of the thermoset material.

1 78. The process according to Claim 77, wherein the carbon black comprises about 20
2 percent by weight of the thermoset material.

1 79. The process according to Claim 74, wherein the non-black inorganic filler is
2 selected from the group consisting of: kaolin, talc, silica, and any combination of the foregoing.

1 80. The process according to Claim 79, wherein the non-black inorganic filler is silica.

1 81. The process according to Claim 80, wherein the silica has in the range of about
2 120 to about 160 square meters per gram surface.

1 82. The process according to Claim 81, wherein the silica has in the range of about
2 150 to about 160 square meters per gram surface.

1 83. The process according to Claim 79, wherein the non-black inorganic filler
2 comprises in the range of 5 to 25 percent by weight of the thermoset material.

Thermoset Vulcanization

1 84. The process according to Claim 70, wherein the thermoset material is vulcanized
2 using organic peroxides.

Thermoset Material Properties

1 85. The process according to Claim 70, wherein the thermoset material has a tensile
2 strength at break in the range of 14 to 31 MPa.

1 86. The process according to Claim 85, wherein the thermoset material has a tensile
2 strength at break of > 24 MPa nominal.

1 87. The process according to Claim 70, wherein the thermoset material has elongation
2 at break in the range of 150 to 750 percent.

1 88. The process according to Claim 87, wherein the thermoset material has elongation
2 at break in the range of 400 to 600 percent.

1 89. The process according to Claim 70, wherein the thermoset material has durometer
2 hardness in the range of 40 Shore A to 95 Shore A.

1 90. The process according to Claim 89, wherein the thermoset material has durometer
2 hardness in the range of 70 Shore A to 80 Shore A.

1 91. The process according to Claim 70, wherein the thermoset material has an abrasion
2 resistance in the range of 0.050 to 0.10 cm³ volume loss measured using the method outlined in
3 ISO-4649-1985(E).

1 92. The process according to Claim 70, wherein the thermoset material has an abrasion
2 resistance of less than 0.08 cm³ volume loss measured using the method outlined in ISO-4649-
3 1985(E).

1 93. The process according to Claim 70, wherein the thermoset material has: a tensile
2 strength at break in the range of 14 to 31 MPa; an elongation at break in the range of 150 to 750
3 percent; a durometer hardness in the range of 40 Shore A to 95 Shore A; and abrasion resistance
4 in the range of 0.050 to 0.10 cm³ volume loss measured using the method outlined in ISO-4649-
5 1985(E).

1 94. The process according to Claim 93, wherein the thermoset material has: a tensile
2 strength at break of greater than 24 Mpa nominal; an elongation at break in the range of 400 to
3 600 percent; a durometer hardness in the range of 70 Shore A to 80 Shore A.

Wall Thickness

1 95. The process according to Claim 70, wherein the wall thickness of the coating is
2 at least 0.13 cm.

1 96. The process according to Claim 95, wherein the wall thickness of the coating is
2 about one-third the thickness of the jacket.

Product by Process

1 97. The cable produced according to the process of any one of Claims 70-96.

Base Cable Structure

1 98. The process according to Claims 51 or 70, wherein the conductor is an electrically
2 conductive material for conducting electricity.

1 99. The process according to Claims 51 or 70, wherein the conductor is a fiber-optic
2 conductor for conducting optical signals.

1 100. The process according to Claims 51 or 70, further comprising: a plurality of
2 conductors intertwined with each other in a generally helical arrangement within the jacket.

1 101. The process according to Claim 100, further comprising a filling material that fills
2 the interstices between the intertwined plurality of conductors.

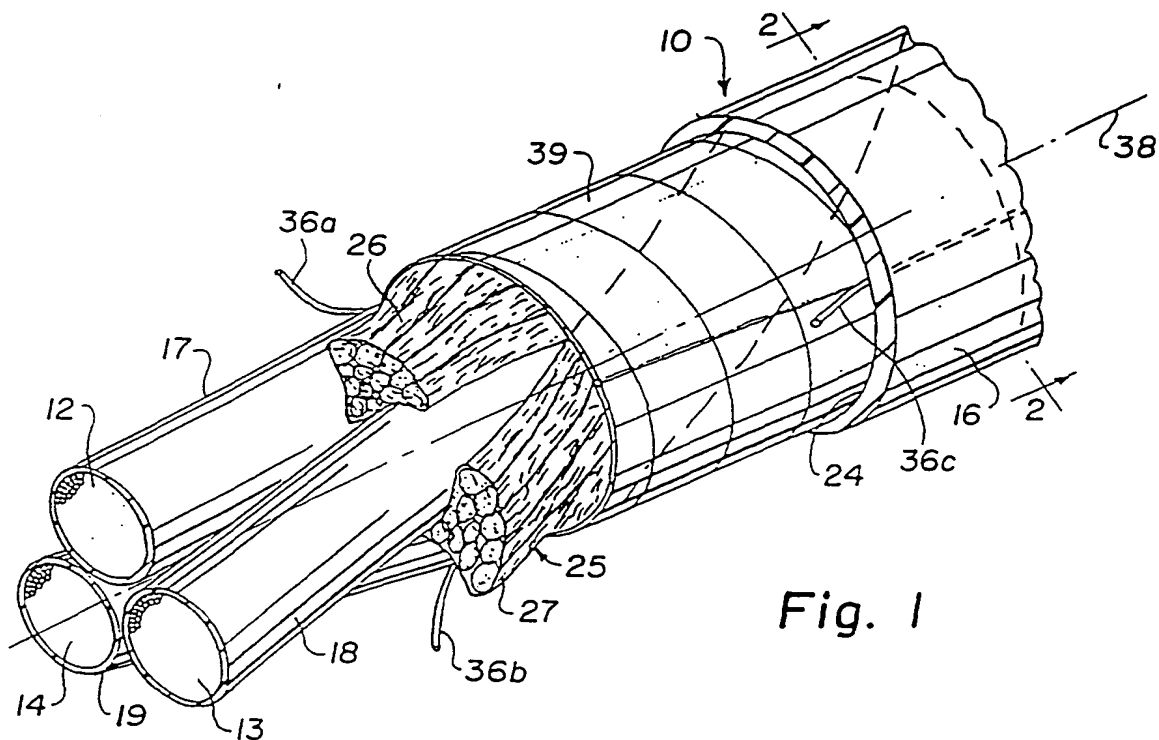


Fig. 1

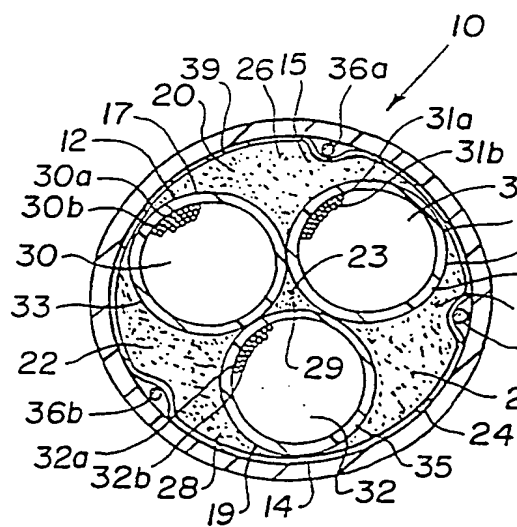


Fig. 2

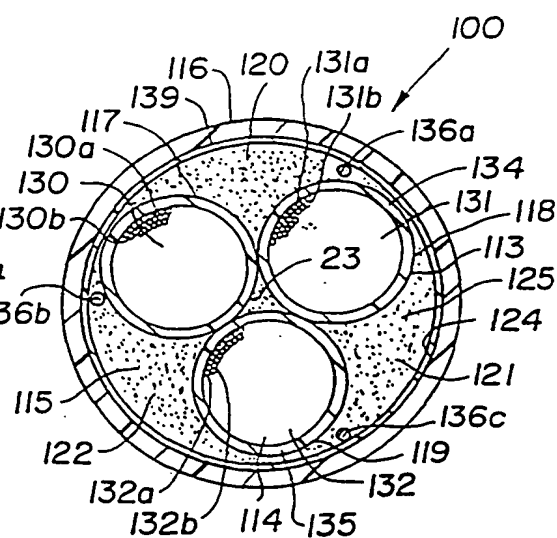


Fig. 3

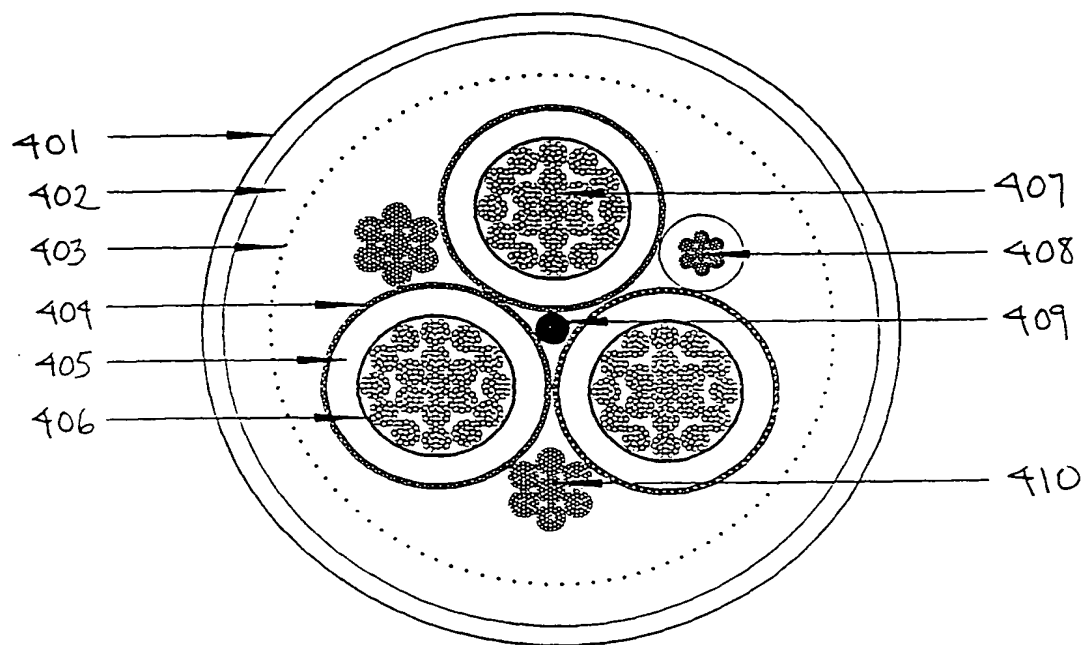


Fig. 9

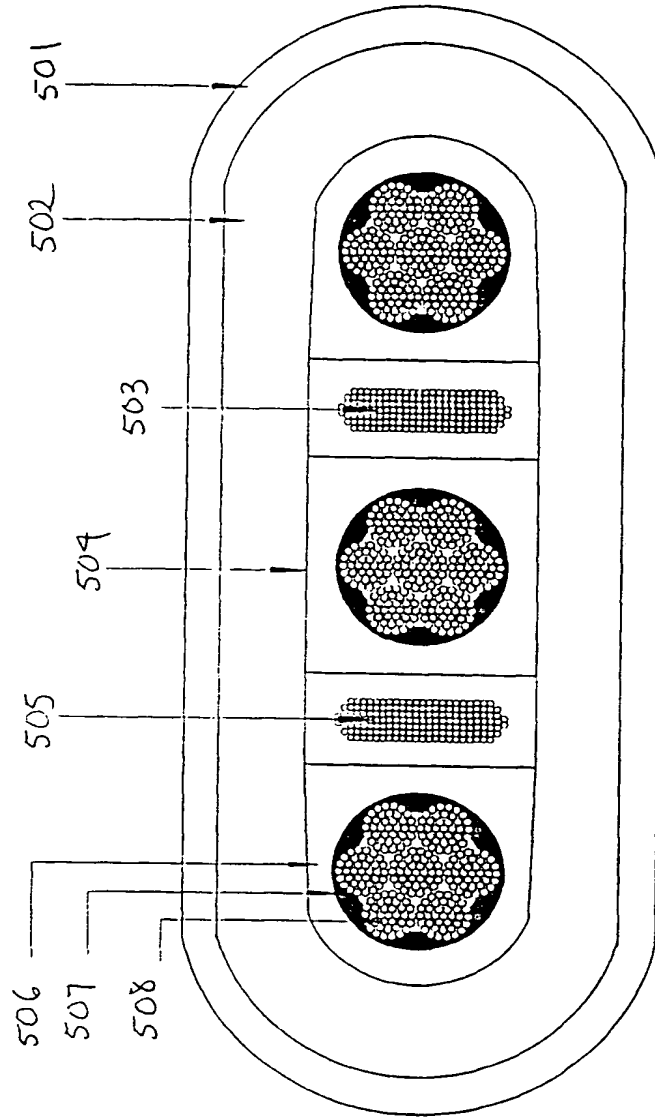


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/26895

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01B 7/00

US CL :174/110R, 110PM, 110S, 113R, 116, 120R, 120AR, 121SR, 124R

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 174/110R, 110PM, 110S, 113R, 116, 120R, 120AR, 121SR, 124R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO APS EAST TEXT SEARCH, NON PATENTED LITERATURE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,167,305 A (ICHIBA et al.) 11 September 1979 (11-09-1979), cols. 1-16, fig 2.	1-6, 20-24, 29-30, 47, 51-54, 70-74, 80, 98 ----- 7-17, 25-28, 31- 33, 35-46, 48-50, 55-69, 75-79, 81- 97, 99-101
X --- Y	US 3,823,255 A (LA GASE et al.) 09 July 1974 (09-07-1974), cols. 1-6, figs 1-2.	1-6, 29-30, 80, 94 ----- 7-28, 31-79, 95- 101



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A Document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

20 FEBRUARY 2000

Date of mailing of the international search report

25 APR 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/26895

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,095,404 A (BABAYAN) 20 June 1978 (20-06-1978), col. 1-8, figs 1-3.	1-101
Y	US 4,631,229 A (MARTENS et al.) 23 December 1986 (23-12-1986), col. 1-24.	1-101
Y	US 4,414,355 A (POKORNY) 08 November 1983 (08-11-1983), cols. 1-8.	1-101
Y	US 5,807,954 A (BECKER et al.) 15 September 1995 (15-09-1995), cols. 1-30.	1-101
A,E	US 5,997,818 A (HACKER et al.) 07 December 1999 (07-12-1999), cols. 1-40, figs 1-5.	1-101
A,E	US 6,003,606 A (MOORE et al.) 21 December 1999 (21-12-1999), cols. 1-38, figs 1-24.	1-101
Y	US 5,274,603 A (ZIBILICH, JR. et al.) 28 December 1993 (28-12-1993), see entire document.	1-101